Supplementary Material

Photosynthesis–nitrogen relationships in tropical forest tree species as affected by soil phosphorus availability: a controlled environment study

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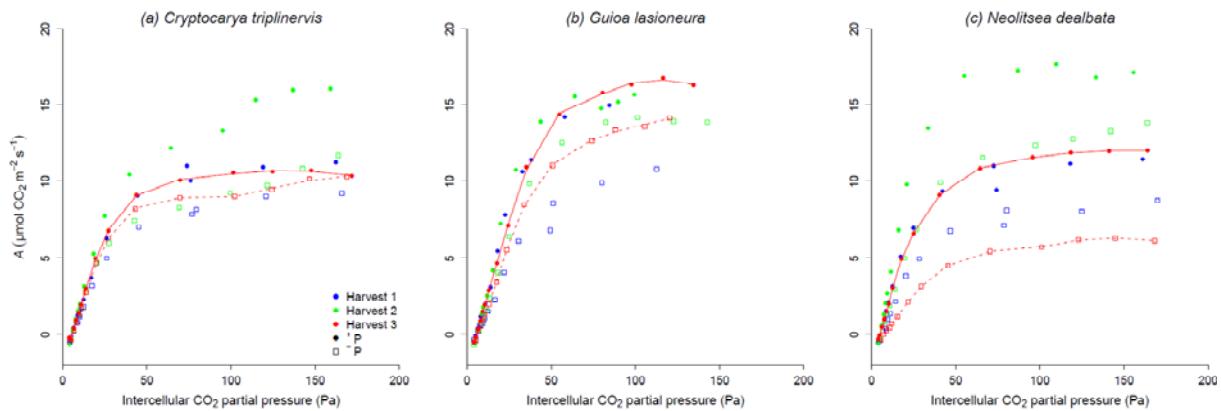[E]Corresponding author. Email: keith.bloomfield@anu.edu.au

Fig. S1. Sample CO_2 response ($A_a \leftrightarrow C_i$) curves for three of the species, displaying differing degrees of response to the experimental treatment. Each point represents the average of four to five replicate saplings. Separate symbols are shown for each harvest (Harvest 1 in blue, Harvest 2 in green and Harvest 3 in red) and each treatment ($^+$P, solid dots; $^-$P, open squares). Lines of best fit (cubic regression splines) are shown for the final harvest only (red lines).
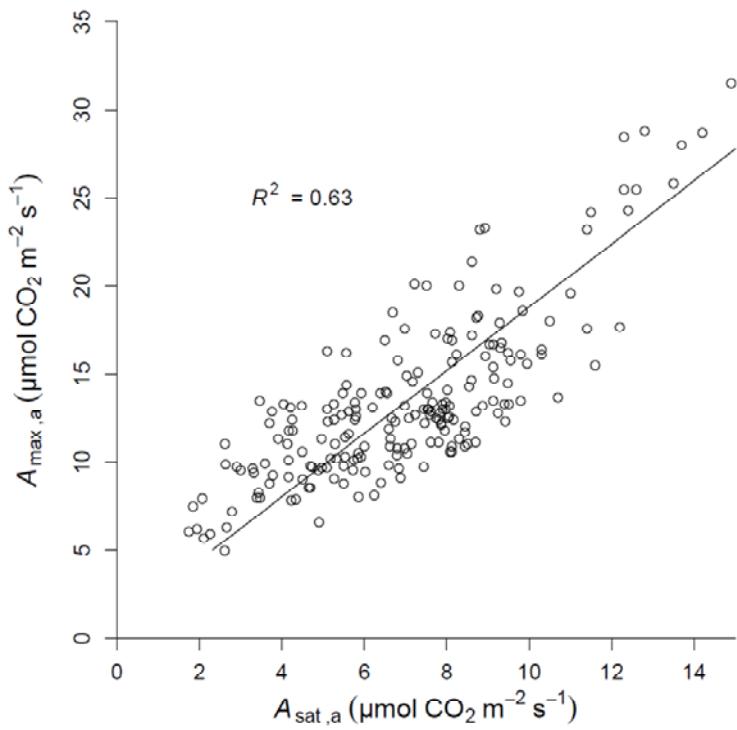
Fig. S2. Scatterplot of the relationship between photosynthetic capacity estimated at elevated ($A_{max,a}$) and ambient CO_2 ($A_{sat,a}$). Points are shown for all species, harvests and treatments; each point represents one sapling.
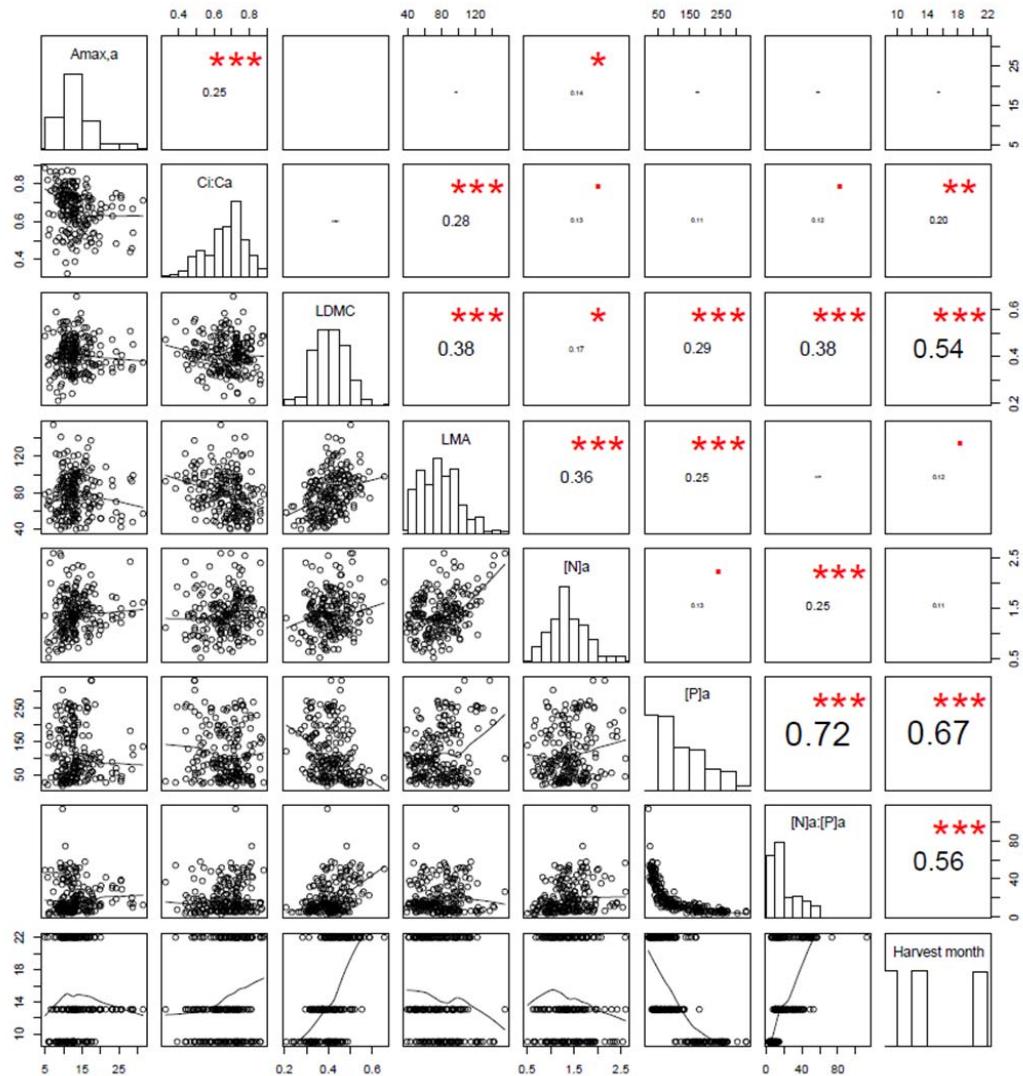
Fig. S3. Pairwise matrix plot of response and explanatory variables. The upper panel contains estimated pairwise correlations and the font size is proportional to the absolute value of the estimated correlation coefficient. Significance codes: *** <0.001, ** <0.01, * <0.05, <0.01. The diagonal panel contains histograms showing frequency distributions for the individual variables. The lower panel contains scatterplots for each variable pairing with a LOESS smoother added to aid visual interpretation. The traits included are area-based photosynthetic capacity ($A_{max,a}$; µmol CO_2 m^{-2} s^{-1}); Ratio of intercellular CO_2 to ambient (C_i:C_a); Leaf dry matter content (ϕ, g g^{-1}); Leaf mass per unit area (M_a g m^{-2}); Leaf nitrogen ([N]$_a$; g m^{-2}); Leaf phosphorus ([P]$_a$; mg m^{-2}) and the Harvest month.
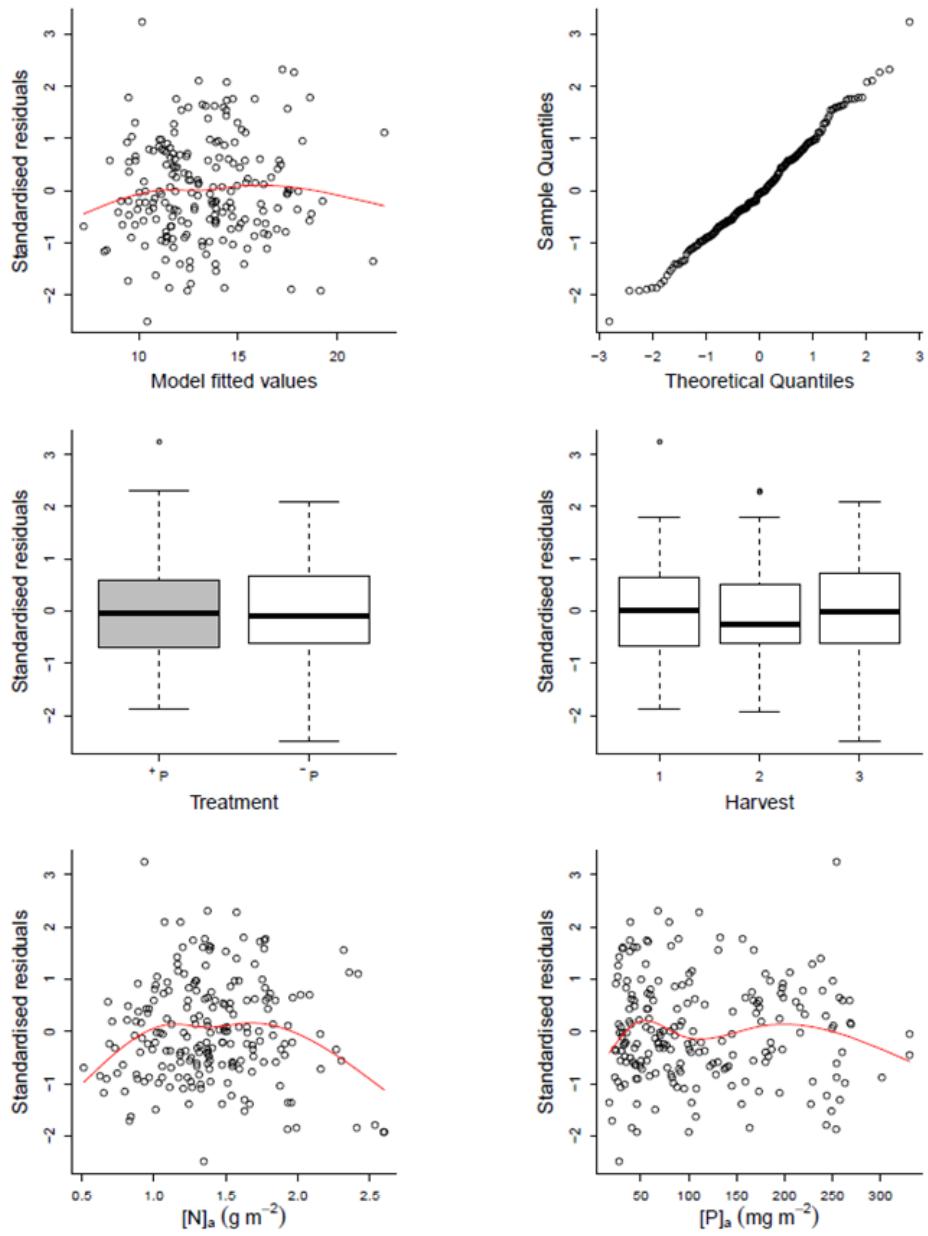
Fig. S4.   Model validation graphs for the random intercept mixed effects model (Equation 1). Standardised residuals are plotted against fitted values and each of the explanatory factors and variables used in the model's fixed and random components. For the scatterplots a local regression smoother has been added to aid visual interpretation.
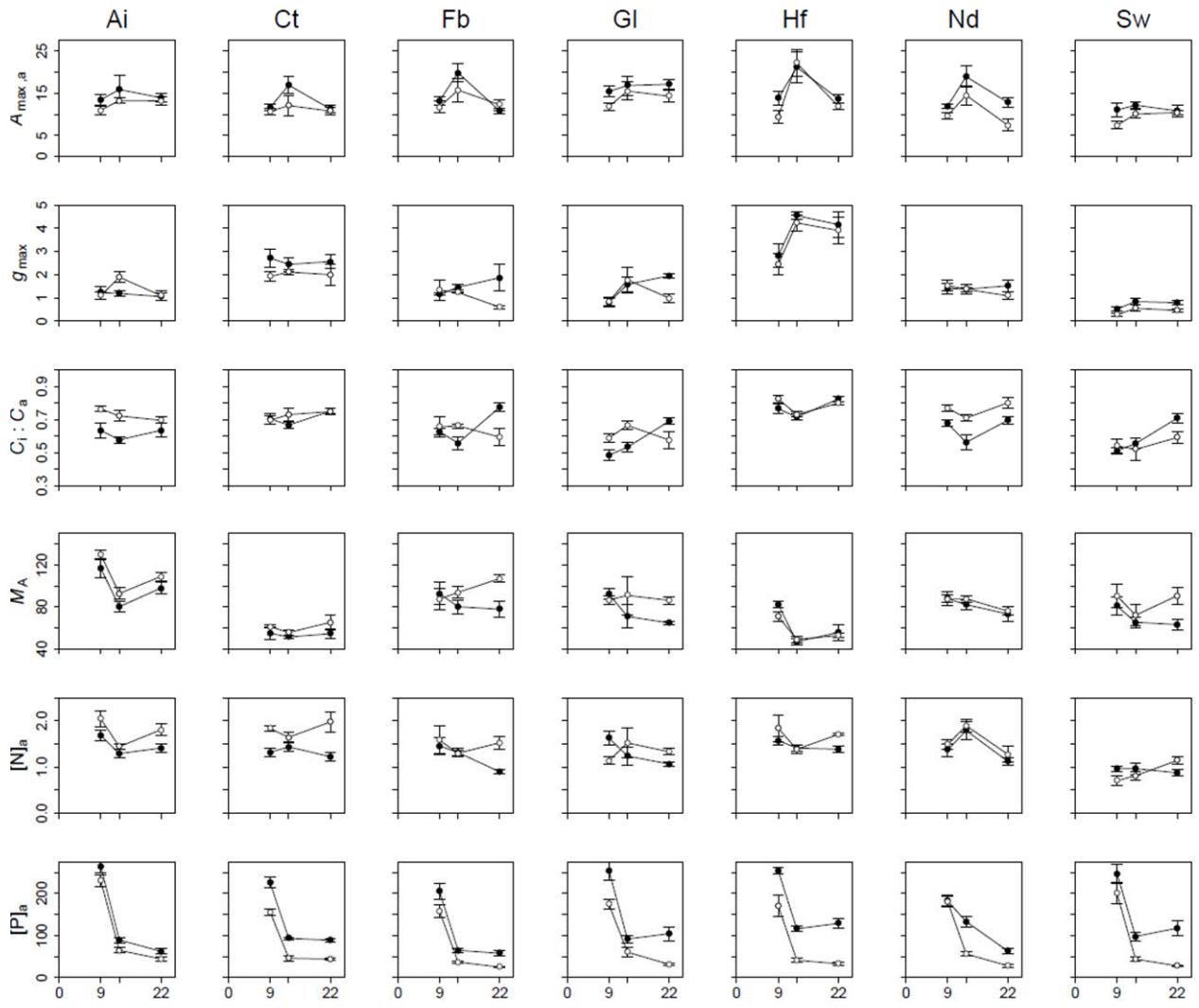
Fig. S5. Key parameters by nutrient Treatment ($^+$P as dark circles, $^-$P as open circles) and Harvest (shown here as months of regime: 9, 13 and 22 months for the successive harvests). A separate column displays each of the seven species (abbreviations are as per **Error! Reference source not found.** in main text). Each point is the mean ($\pm$ s.e.) of four to five replicates. The y axes descriptors and units of measure are: Photosynthetic capacity, area basis (μmol CO_2 m^{-2} s^{-1}); Maximum stomatal conductance (mmol H_2O g^{-1} s^{-1}); Ratio of intercellular CO_2 to ambient (dimensionless); Leaf mass per unit area (g m^{-2}); Total leaf nitrogen, area basis (g m^{-2}) and Total leaf phosphorus, area basis (mg m^{-2}).

Table S1. Outputs from lme model variants. The models vary only in their fixed components: variables expressed per unit leaf area (a and c) or per unit dried mass (b and d); and whether the data have been $\log_{10}$ transformed (c and d) or not (a and b). In each case, photosynthetic capacity (A_{max}) as the response variable. Parameter values, standard errors (s.e.), degrees of freedom (*d.f.*), *t*- and *p*-values for the explanatory variables: factors (nutrient treatment, harvest) with covariates leaf nitrogen [N] and phosphorus [P] centred on their respective means. Treatments are $^+$P and $^-$P; consecutive Harvests are after 9 (Harvest 1), 13 (Harvest 2) and 22 (Harvest 3) months of treatment. The response variable in each case is photosynthetic capacity A_{max}.

a) Variables on an area basis

Source	Value	s.e.	d.f.	t-value	p-value
Treatment $^+$P, Harvest 1	11.179	0.892	190	12.538	< 0.0001
Treatment $^-$P	- 1.988	0.500	190	- 3.973	0.0001
Harvest 2	6.136	1.023	190	5.997	< 0.0001
Harvest 3	3.196	0.932	190	3.428	0.0007
$[N]_a$	4.622	0.872	190	5.299	< 0.0001
$[P]_a$	0.014	0.006	190	2.407	0.0171
Treatment $^-$P : $[N]_a$	- 2.983	0.962	190	- 3.101	0.0022

b) Variables on a mass basis

Source	Value	s.e.	d.f.	t-value	p-value
Treatment $^+$P, Harvest 1	136.667	10.797	189	12.658	< 0.0001
Treatment $^-$P	- 23.771	5.330	189	- 4.460	< 0.0001
Harvest 2	93.171	12.438	189	7.491	< 0.0001
Harvest 3	50.647	10.630	189	4.765	< 0.0001
M_A	- 0.480	0.159	189	- 3.018	0.0029
$[N]_m$	3.337	0.573	189	5.828	< 0.0001
$[P]_m$	20.061	5.649	189	3.551	0.0005
$M_A : [N]_m$	- 0.059	0.022	189	- 2.729	0.0069

c) Variables on an area basis, $\log_{10}$ transformed

Source	Value	s.e.	d.f.	t-value	p-value
Treatment $^+$P, Harvest 1	1.028	0.032	190	32.092	< 0.0001
Treatment $^-$P	- 0.062	0.019	190	- 3.306	0.0011
Harvest 2	0.193	0.032	190	6.084	< 0.0001
Harvest 3	0.127	0.035	190	3.671	0.0003
$\log_{10}[N]_a$	0.574	0.091	190	6.316	< 0.0001
$\log_{10}[P]_a$	0.131	0.052	190	2.531	0.0122
Treatment $^-$P : $\log_{10}[N]_a$	- 0.321	0.109	190	- 2.950	0.0036

d) Variables on a mass basis, $\log_{10}$ transformed

Source	Value	s.e.	d.f.	t-value	p-value
Treatment $^+$P, Harvest 1	2.208	0.020	191	112.061	< 0.0001
Treatment $^-$P	- 0.102	0.014	191	- 7.410	< 0.0001
Harvest 2	0.140	0.020	191	6.943	< 0.0001
Harvest 3	0.043	0.014	191	2.998	0.0031
$\log_{10}M_A$	- 0.481	0.082	191	- 5.883	< 0.0001
$\log_{10}[N]_m$	0.337	0.069	191	4.872	< 0.0001

Table S2. Tests of the assumption of linearity (Pearson's correlation, *r*) for the overall bivariate relationships at Harvest 3 (without controlling for treatment)

The response variables are carboxylation capacity ($V_{\text{cmax,a}}$; µmol CO_2 m^{-2} s^{-1}) and the rate of electron transport ($J_{\text{max,a}}$; µmol e$^-$ m^{-2} s^{-1}); the independent variables are leaf nitrogen ($[N]_a$, g m^{-2}) and leaf phosphorus ($[P]_a$, mg m^{-2}). d.f., degrees of freedom

Response	Bivariate	d.f.	*r*	*P*-value
$V_{\text{cmax,a}}$	$[N]_a$	65	0.313	0.010
$V_{\text{cmax,a}}$	$[P]_a$	65	0.127	0.307
$J_{\text{max,a}}$	$[N]_a$	65	0.096	0.441
$J_{\text{max,a}}$	$[P]_a$	65	0.271	0.027